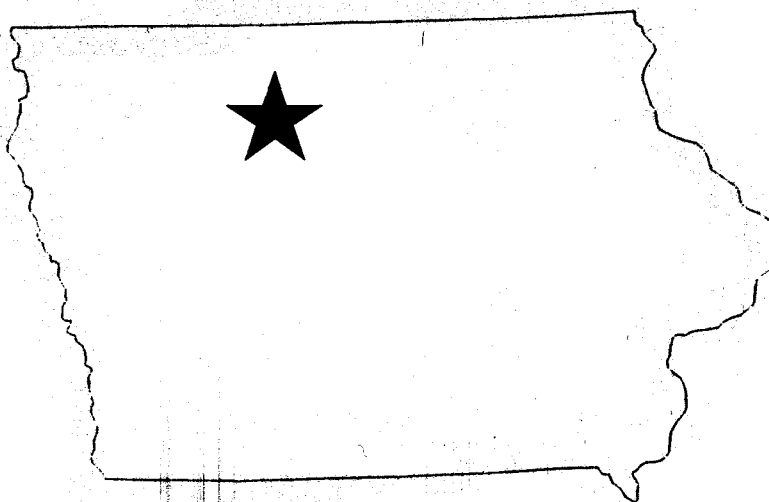


**U.S. Fish and Wildlife Service
Region 3
Contaminants Program**

**Union Slough National Wildlife Refuge,
Iowa
Contaminants Investigation
Final Report**



**U.S. Fish and Wildlife Service
4469 - 48th Avenue Court
Rock Island, Illinois 61201
2000**





Union Slough National Wildlife Refuge Contaminants Investigation



This document reports the results of a pollution study that was conducted at the refuge between 1995 and 1997. The study was a cooperative effort by the refuge staff and contaminants specialists from the Rock Island Field Office as part of the U.S. Fish and Wildlife Service's refuge contaminants program.

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- ▶ Summary
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Great Lakes - Big Rivers Region | Union Slough National Wildlife Refuge | Rock Island Field Office

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Credit Authored by Michael Coffey, Contaminants Specialist, U. S. Fish and Wildlife Service, Rock Island Field Office, Rock Island, IL (June 2000)



SUMMARY [Back to Main Menu](#)

Technical staff from the U.S. Fish and Wildlife Service studied water quality at Union Slough National Wildlife Refuge, Kossuth County, Iowa between 1995 and 1997. This study was conducted because earlier investigations found polluted sediments at the refuge. The study methods included mapping sediment quality, monitoring waters for agricultural pollutants, and confirmation of heavy metal bioaccumulation in bird eggs. The refuge's wetland resources are mostly cattail marsh and open water pools. The water sources for these wetlands are primarily tile drainage effluent. Parts of the refuge had elevated ammonia and selenium concentrations above expected background concentrations. Elevated ammonia concentrations were likely related to the breakdown of large volumes of organic matter loaded to the sediments in the highly productive and eutrophic waters. Sediment selenium enrichment was consistent with previous investigations. The source of the selenium is not known, but could be predominately leached from seleniferous soils in the watershed. Selenium and mercury did bioaccumulate in merganser eggs at slight to moderate hazard levels. Adverse affects to birds from exposure to these heavy metals were predicted, but this needs to be confirmed by additional studies. Insecticide chemicals were not detected by the monitoring plan, but refuge wildlife that foraged at cropfield edges were at risk of insecticide exposure. The monitoring data indicated that herbicide chemicals were transported through the refuge ecosystem. The types of herbicide brands detected at the refuge followed chemical use patterns in the watershed. The concentrations of herbicide chemicals detected in refuge surface water were below lethal benchmark values for aquatic life. However, the concentrations of herbicide chemicals detected in surface water were above levels that may stress aquatic plants. The monitoring data also indicated nutrient (ammonia, nitrate and phosphate) rich tile drainage water and pool surface water. Blooms of aquatic nuisance plants and fish kills were observed during the study period. We suggest that the loading of nutrients was sufficient to cause changes to the structure and composition of refuge plant communities and cultural eutrophication of refuge surface water resources. The altered ecological communities in the polluted areas function to treat nitrogen inputs, providing less diverse wildlife habitats and food resources. Several wetland and watershed management strategies are discussed to help managers increase habitat diversity and benefits to migratory birds. Refuge operation specialists have implement several watershed initiatives to date. We should not become discouraged or impatient for success because it is important to note that an increment of improvement in the watershed will not necessarily result in an increment of improvement in refuge water quality. It is possible that little or no ecological change may occur or be observed at the refuge in our lifetime until a critical level is reached in the watershed resulting in a noticeable shift in refuge environmental habitat quality in the future.

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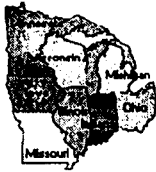
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INTRODUCTION [Back to Main Menu](#)

This document reports and interprets water quality data for Union Slough National Wildlife Refuge, Kossuth County, Iowa ([Figure 1](#)). The data include results from chemical analyses of water, sediment samples and biological specimens.

The water quality monitoring project was conducted between 1995 and 1997 by agency staff from Union Slough National Wildlife Refuge and Rock Island Ecological Services Field Office. The project was jointly funded by the U.S. Fish and Wildlife Service's Division of Refuges and Division of Ecological Services / Environmental Contaminants.

Background

In 1986, biologists from the U.S. Fish and Wildlife Service started a program to survey and catalog pollution problems on national wildlife refuges. As part of this program, in 1990 and 1991, preliminary studies were completed at the Union Slough National Wildlife Refuge to determine if priority pollutants (organochlorine chemicals and heavy metals) were present in refuge wetland resources (Copeland 1992).

The findings for the preliminary studies indicated that no organochlorine pollution from chemicals such as DDT, chlordane or PCB was detected in refuge wetland sediments. The sediment samples had heavy metal concentrations that were above expected background concentrations ([Table 1](#)). The 1990 and 1991 sediment heavy metal results were consistent with an investigation completed in the 1981 by the University of South Dakota (Martin and Hartman 1984) suggesting that this sediment quality condition has existed for at least two decades. These findings prompted this study to more completely characterize water quality and contaminant problems for the refuge.

The first phase for this study was to gather relevant contaminants information for the watershed. This included an inventory of local agricultural chemical use patterns and review of any water quality data for rivers and streams that feed into the refuge. There are four surface water sources for the refuge that include Buffalo Creek, Blue Earth River and a two un-named streams that extend beyond the refuge boundary line (Goche Pasture Ditch and Harm's - Gray Ditch) ([Figure 2](#)). The refuge serves as the headwaters for the Blue Earth River, which ordinarily flows to the north away from the refuge open water management pools. Buffalo creek enters the refuge from the east and flows through the southern fifth of the refuge. It ordinarily flows away from the refuge open water management pools and empties into the East Fork of the Des Moines River. In addition to these surface water sources, there are over 65 tile drainage system outlets that empty directly into the refuge open water management pools not

counting those tile drains that empty into Buffalo Creek ([Figure 3](#)).

Surrounding farmers and commercial pesticide applicators were periodically interviewed during the study period. The interview information indicated that 19 pesticide brands were used in the watershed for the production of corn and soybean between 1995 and 1997 ([Table 2](#)). Note that persistent herbicide chemicals such as atrazine was widely used in the earlier part of the study, but was followed by a change at the end of the study to the use of a variety of other newly marketed brands.

Buffalo Creek and the Blue Earth River carried a variety of contaminants including pesticide chemicals and nutrients (data from this study, IADNR 1997 and MSWCD 1996). The contaminants in Buffalo Creek were transported into refuge wetlands because a reach of this small river flows through the refuge and is a source of surface water for this part of the refuge. There were no historic water quality data for effluent from the tile drainage systems that discharge into refuge wetlands.

Study Objectives

The four objectives for the study are outlined below.

1. Characterize aquatic sediment quality for the refuge.
2. Monitor tile drainage water and pool surface water for insecticide, herbicide and nutrient chemicals.
3. Confirm bioaccumulation of the heavy metal chemicals that can biomagnify in the food chain.
4. Help develop water quality management alternatives for the refuge.

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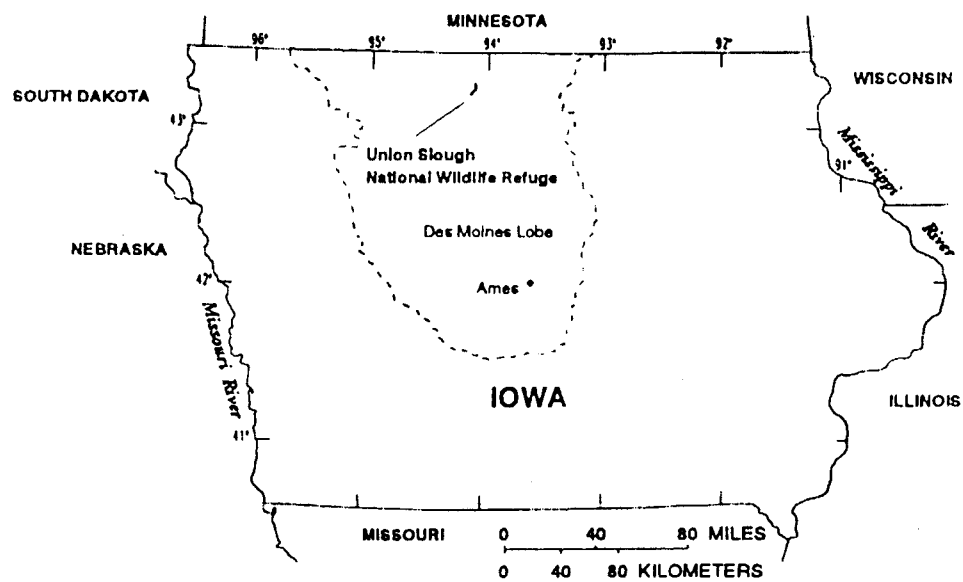


Figure 1. Location of Union Slough National Wildlife Refuge, Iowa (from USGS 1998).

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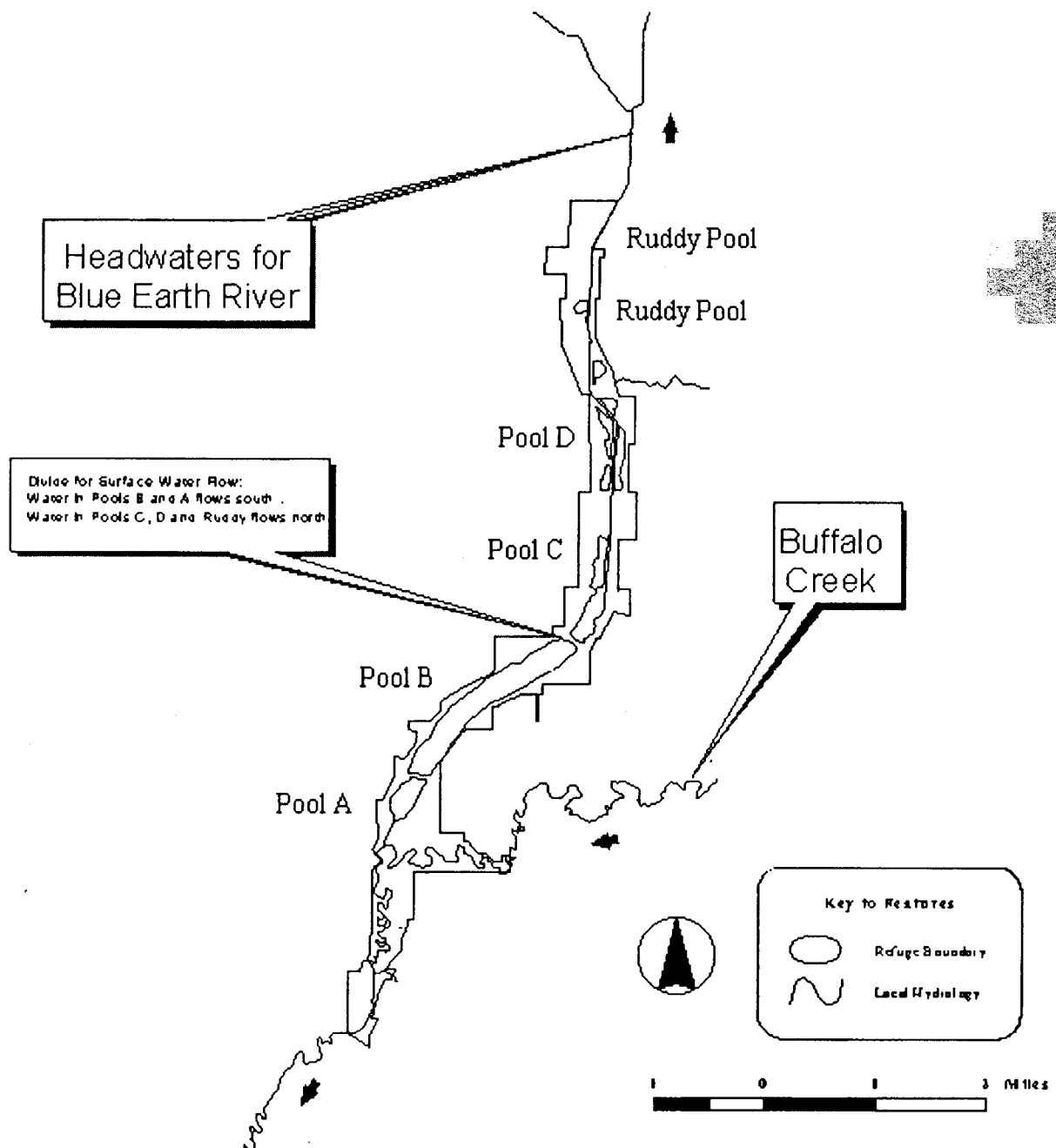


Figure 2. Surface water resources for Union Slough National Wildlife Refuge, Iowa.

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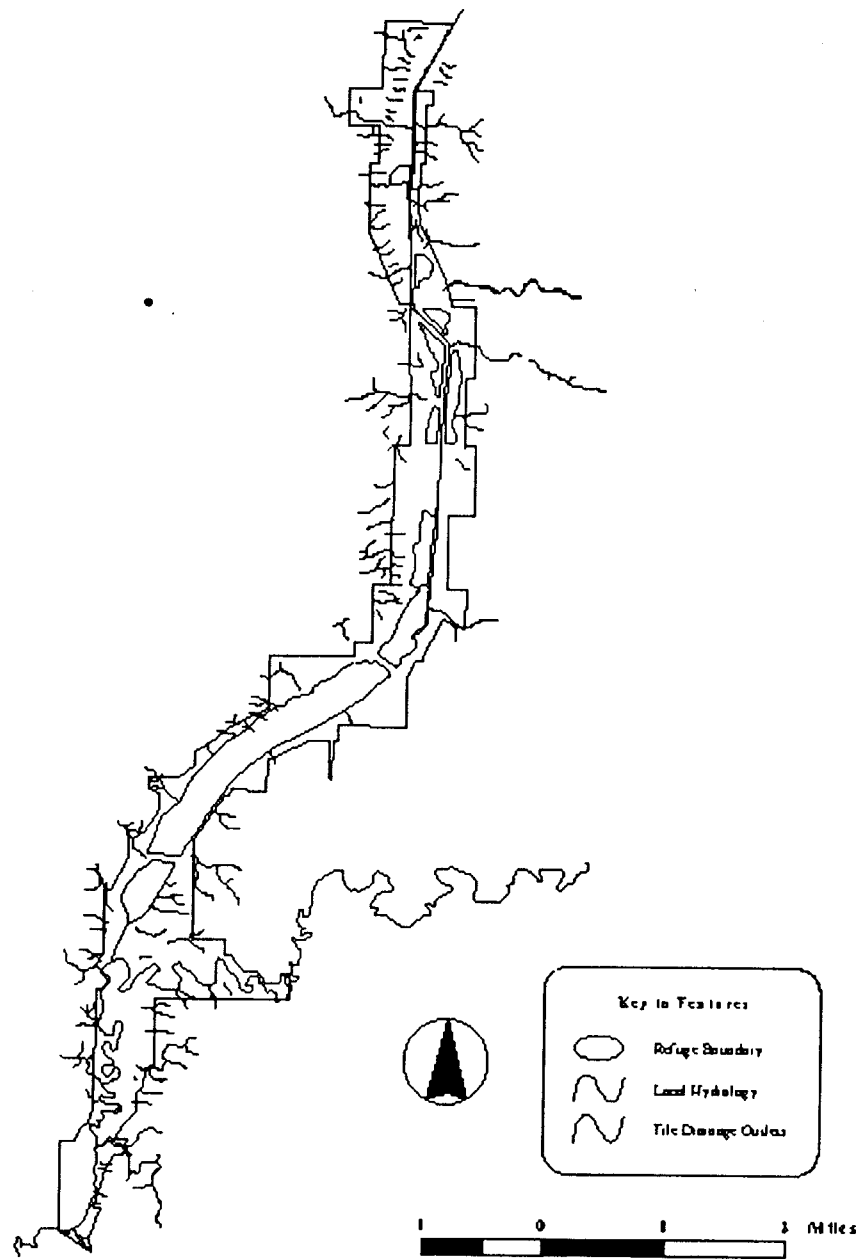


Figure 3. Locations of agricultural subsurface tile drainage systems and outlets at Union Slough National Wildlife Refuge, Iowa.

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Table 1. Historic maximum arsenic and heavy metal concentrations detected in sediments at Union Slough National Wildlife Refuge, Kossuth County, Iowa and average soil background concentrations (micrograms per gram, dry weight). [Back to Introduction](#)

Analyte	1984 ¹	1991 ²	U.S. Soils ³	Contaminant Biomagnify	Contaminant of Interest
Arsenic	Not Reported	6.1	6.7 - 13	No	Possible
Cadmium	0.55	0.6	<1.0	No	No
Chromium	Not Reported	23	11 - 76	No	No
Copper	Not Reported	18	8.7 - 33	No	No
Lead	14	12	2.6 - 28	No	No
Mercury	0.04	0.054	<0.16	Yes	Yes
Nickel	Not Reported	18	20	No	No
Selenium	5.1	1.9	0.27 - 0.73	No	Yes
Zinc	Not Reported	104	25 - 67	No	Yes

¹ Martin and Hartman 1984

² Copeland 1992

³ Average elemental concentrations in surficial materials (Conner *et al.* 1975)

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Table 2. Information on popular pesticides used row crop fields adjacent to Union Slough National Wildlife Refuge between 1995 and 1997. *Back to Introduction*

Chemical	Trade Name	Use
Atrazine	Atrazine®	Corn pre-emergent herbicide
Dicamba	Banvel®	Corn post-emergent herbicide
Atrazine + Bromoxynil	Buctril®	Corn pre-emergent herbicide
Atrazine + Alachlor	Bullet®	Corn pre-emergent herbicide
Terbufos	Counter®	Systemic insecticide
Metolachlor	Dual®	Corn pre-emergent herbicide
Tefluthrin	Force®	Systemic insecticide
Carbofuran	Furadan®	Systemic insecticide
Caboxide + Diazinon + Lindane	Germate Plus® & Kick Start®	Systemic fungicide and insecticide
Atrazine + Bentazone	Laddock®	Corn pre-emergent herbicide
Chlorpyrifos	Lorsban®	Systemic insecticide
Atrazine + Dicamba	Marksman®	Corn pre-emergent herbicide
Sulfonylurea	Pinnacle® & Synchrony®	Soybean post-emergent herbicide
Permethrin	Pounce®	Systemic insecticide
Pendimethalin	Prowl®	Soybean herbicide
Imidazolinone	Pursuit®	Soybean pre-emergent herbicide
Acetochlor	Surpass®, Harness®	Corn pre-emergent herbicide
Trifluralin	Treflan®	Soybean pre-emergent herbicide

Systemic insecticides were generally used at corn planting time (early April through mid May) for rootworm control on fields that were not rotated to soybean, and again on young plants (June through July) for corn borer and/or cut worm control.

Seed corn was coated with systemic fungicide chemicals and insecticide chemicals for some users.

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SAMPLING LOCATIONS, TIMES and RATIONALE [Back to](#)

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Tile drainage water, pool surface water, aquatic sediments and hooded merganser eggs were collected and tested for target chemicals from field sampling stations located throughout the refuge. The target chemical list was generated by a method developed by the U.S. Fish and Wildlife Service's [Contaminant Assessment Process \(CAP\)](#). The lists of target chemicals for each media (water, sediments and biological specimens) are provided in the sections outlined below. The field sampling stations were distributed systematically throughout the refuge at all pool inlet and outlet structures and at suspected hot spots also known as potentially contaminated areas (PCAs). The PCAs were delineated by a method developed by the U.S. Fish and Wildlife Service [Contaminant Assessment Process \(CAP\)](#). Select topic below for field sampling locations and frequency.

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Upper St. Joseph National Wildlife Refuge Contaminants Investigation Final Report 1999 • USFWS RIFD



Sampling Locations and Times Information

Water Quality

Water samples were collected monthly (except during the winter ice freeze down) at thirteen fixed monitoring stations from throughout the refuge during the study period. The monitoring stations were set up at all of the outlet structures between the five open water pools on the refuge and at seven representative tile drainage water outlets. See [Figure 4](#) for map of water monitoring stations. The water samples were tested for a suite of herbicide chemicals, ammonia, phosphates and nitrate.

Some herbicide chemicals could be transported to the refuge as pulse events in tile drainage water or by surface run-off during storm events between monitoring times and be flushed out of the system therefore going undetected. Retention times were as low as 2.2 days during the spring pesticide application season (USGS 1996). The herbicide analytical scan does not test for all possible herbicide chemicals in use. The routine analytical scan tested for seven of the 19 herbicide chemicals in use for the watershed during the study period. An attempt was made to balance short frequency for the monitoring intervals, detection of the major and widely used chemicals and budget. [Back to Start Menu](#)

Sampling Locations and Times Information

Sediment Quality

Aquatic sediment samples were collected in 1995 at the ends of each open water pool and the center of the one long pool (Pool C). See [Figure 5](#) for a map of the sediment sampling locations. The sediment samples were tested for the heavy metals of interest, ammonia, phosphates and grain size distribution. [Back to Start Menu](#)

Sampling Locations and Times Information

Insecticide Biomonitoring

Insecticide chemicals are generally toxic to aquatic life, are very short lived, can pulse through the system and are present at concentrations often below analytical detection limits. We believed that the water quality monitoring plan had the potential to not detect insecticide chemicals if present in the system for short periods at trace concentrations. We elected to monitor the responses in fish enzymes as an indication of exposure to and presence of insecticide chemicals in the system. Most insecticide chemicals are inhibitors of the nervous system enzyme cholinesterase. Caged fish were deployed at many of the water quality monitoring stations and at

a reference station. Fish were removed every six weeks and tested for cholinesterase activity. Enzyme activities from several areas in the refuge were compared to enzyme activity of fish from an area known to be free from insecticide exposure. Refer to the separate report on Insecticide Biomonitoring for a detailed description of the sampling locations and times. [Back to Start Menu](#)

Sampling Locations and Times Information

Bird Egg Chemistry

The refuge maintains over 300 artificial nest boxes for woodduck production. Some of these boxes are used by hooded mergansers. Hooded mergansers feed on fish and other small aquatic animals. For these reasons hooded merganser fresh eggs were collected and tested for the heavy metals of interest for the refuge that can biomagnify in the food chain (mercury and selenium). The eggs were collected in 1997 from 17 nest boxes evenly distributed in the grassy areas on either side of the open water pools and spread out throughout the refuge. [Back to Start Menu](#)

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- Station 1. Outlet Ruddy Pool
 - Station 2. Outlet Pool D
 - Station 3. Outlet Pool C
 - Station 4. Outlet Pool B
 - Station 5. Outlet Pool A
 - Station 6. Tienan's Dam on Buffalo Creek
 - Station 7. R. Goche Tile Drainage Outlet
 - Station 8. Stork's Tile Drainage Outlet
 - Station 9. Antione's Tile Drainage Outlet
 - Station 10. Cushman's Tile Drainage Outlet
 - Station 11. Harm's & Gray's Tile Drainage Outlets
 - Station 12. County Tile - South
 - Station 13. County Tile - North

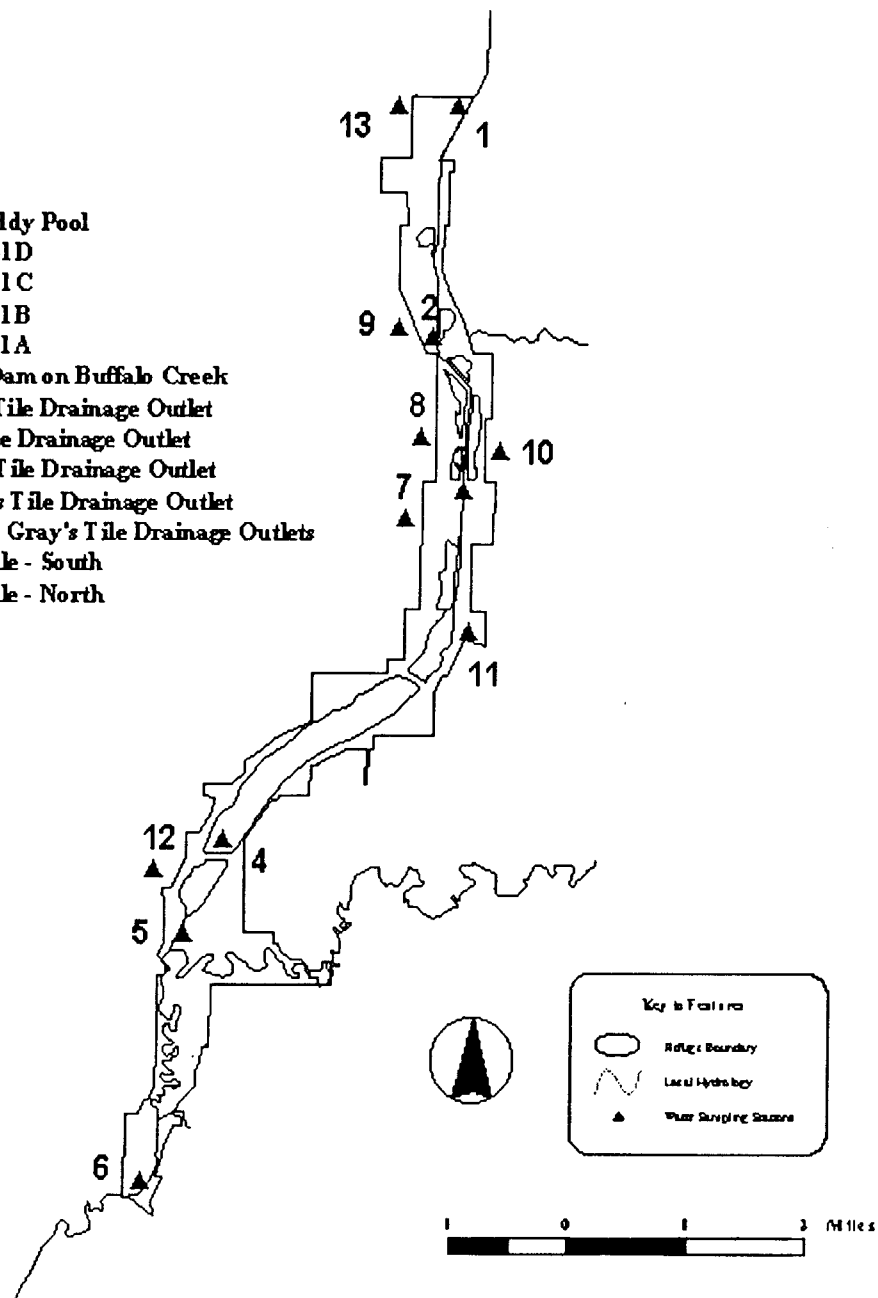


Figure 4. Locations of surface water sampling stations at Union Slough National Wildlife Refuge, Iowa.

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Explanation

- Station 1. Pool B South
- Station 2. Pool B Center
- Station 3. Pool B North
- Station 4. Pool C South
- Station 5. Pool C North
- Station 6. Pool D South
- Station 7. Pool D North
- Station 8. Ruddy Pool

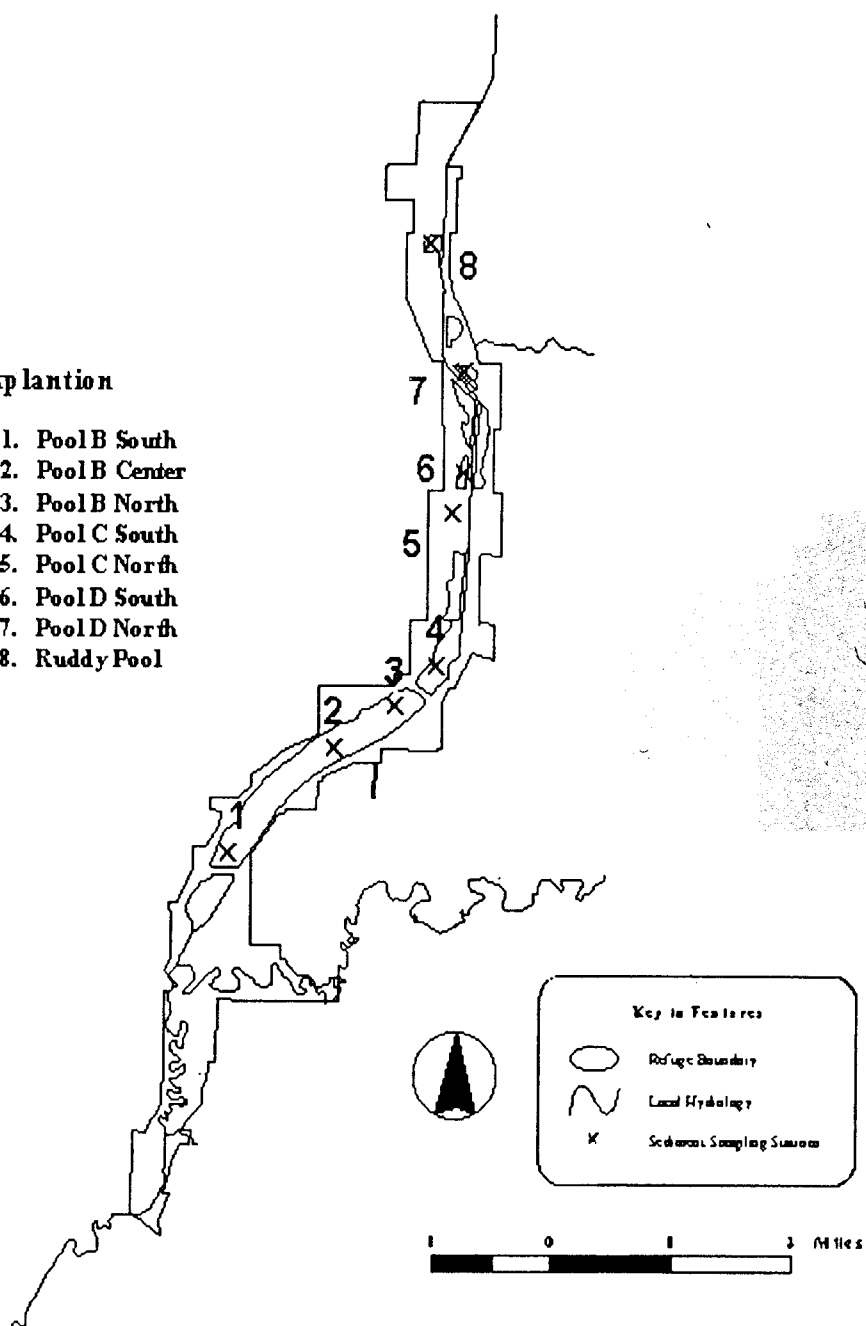
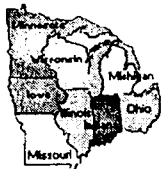


Figure 5. Locations of aquatic sediment sampling stations at Union Slough National Wildlife Refuge, Iowa.

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Union Slough National Wildlife Refuge Contaminants Investigation Final Report 1999 (USFWS RIFC)

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Water Quality

The water sample was collected directly into bottles below the surface film. The samples were maintained chilled in a cooler with blue ice and transported to the office for storage in a standard refrigerator. The samples were forwarded to a contract laboratory (University of Iowa Hygienic Laboratory, Iowa City and Des Moines, Iowa) for analysis within recommended holding times. The water samples were analyzed for a variety of pesticide and nutrient chemicals ([Table 3](#)).

A Solomat model 520c (Neotronics Company, Norwalk, CT) water quality meter was used to measure surface water temperature ($^{\circ}\text{C}$), pH, dissolved oxygen (milligrams per liter - mg/L) and conductivity (microSiemens per centimeter - $\mu\text{S}/\text{cm}$). Measurements were taken each time chemistry samples were collected. Readings were taken at between six inches and one foot below the surface.

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Sediment Quality

Aquatic sediment samples were collected with a standard Ekman dredge (Wildco Company, Saginaw, MI). The dredge was dropped into the substrate, closed and raised for inspection. Upland soil samples were collected with a standard garden post hole digger. The contents of the sampling device were emptied into a stainless steel bowl if it was at least three quarters full. If the grab was not complete, another grab was attempted approximately two meters in any direction from the last attempt.

The material in the bowl was gently mixed with a stainless steel spoon and portions were scooped into chemically clean jars for analyses.

The samples were maintained chilled in a cooler with blue ice and transported to the office for storage in a refrigerator. The samples were forwarded to the contract laboratory for analyses within recommended holding times. The sediment samples were analyzed for nutrients, a group of heavy metals and grain size distribution ([Table 4](#)).

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Insecticide Biomonitoring

Caged fish were deployed at the water quality monitoring stations. Fish were removed every six weeks and tested for cholinesterase enzyme activity. Enzyme activities from fish collected at

several areas in the refuge were compared to enzyme activity of fish from an area suspected of being free from insecticide exposure. View or download the technical report on [Insecticide Biomonitoring](#) for a detailed description of the field and analytical methods.

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Bird Egg Chemistry

One fresh egg was removed each of the selected nest boxes. The eggs were maintained chilled in a cooler with blue ice and transported to the office for storage in a refrigerator. The eggs were weighed and measured with a digital caliper. The size measurements included length and two perpendicular width dimensions. The end was cut open with a chemically clean scalpel and the contents poured into chemically clean jars. The egg contents were frozen and shipped to the contract laboratory for chemical analysis within recommended holding times. The egg specimens were analyzed for mercury and selenium ([Table 5](#)).

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Quality Control Plan

The quality control plan included decontamination procedures, instrument calibration and quality assurance tests.

Decontamination Procedures

Instrument probes and sensors were rinsed with de-ionized water between uses. The sediment sampling gear was cleaned with surface water, rinsed with acetone and rinsed again with deionized water between uses. The de-ionized rinse water used on the sediment sampling gear was occasionally collected for analysis to test for cross contamination.

Instrument Calibration

The water quality meter was calibrated and checked annually by the manufacturer. The calibration standards for the water quality meter were obtained from the manufacturer.

Quality Assurance Tests

We randomly collected duplicate field samples of water and aquatic sediments and submitted them along with the original samples for chemical analysis along with the original samples. The results of the duplicate and original samples were compared as a test of laboratory performance.

The contract laboratories also analyzed split samples, blank samples and spiked samples according to their quality control program (<http://www.uiowa.edu>)

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Table 3. Analytical methods, detection limits and preservative types for water quality samples.

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Analyte	Method	Detection Limit	Preservative
Ammonia-nitrogen	Automated phenate	0.1 mg/L ¹	Sulfuric Acid
Nitrate-nitrogen	Automated cadmium reduction	0.1 mg/L	Sulfuric Acid
Phosphate-phosphorus	Automated ascorbic acid	0.1 mg/L	Sulfuric Acid
Herbicide Scan ²	HPLC ³	1.0 µg/L ⁴	Refrigeration

¹ Milligrams per liter or parts per million

² Atrazine, metolachlor, alachlor, trifluralin, acetochlor, pendimethalin and imidazolinone

³ High Pressure Liquid Chromatography

⁴ Micrograms per liter or parts per billion

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Table 4. Analytical methods and detection limits for the sediment quality samples.

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Analyte	Method	Detection Limit
Ammonia-nitrogen	Automated phenate	1 mg/Kg ¹
Phosphate-phosphorus	Automated ascorbic acid	1 mg/Kg
Grain size distribution	Dry weight and sieve	N/A
Total organic carbon content	Colormetric	N/A
Herbicide scan ²	HPLC ³	1 mg/Kg
Heavy metal group scan ⁴	ICP ⁵	0.1 mg/Kg

¹ Milligrams per kilogram or parts per million

² Atrazine, metolachlor, alachlor, butylate, trifluralin and acetochlor

³ High Pressure Liquid Chromatography

⁴ Arsenic, selenium and zinc

⁵ Inductively Coupled Plasma Emission Spectroscopy

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Table 5. Methods and detection limits for bird egg contents chemical analysis.

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Analyte	Analytical Method	Quantitation Limit
Mercury	Cold vapor AA ¹	0.1 µg/g ²
Selenium	Graphite furnace AA	1.0 µg/g

¹ Atomic Absorption Spectroscopy

² Micrograms per gram or parts per million

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Open Water Pools and Rivers - Nutrient Data Summary for April 1995 to October 1996

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Nitrate+Nitrite as Nitrogen (milligrams per liter) _____

Location	Number of Samples	Number of Detects	Detection Frequency	Detected Minimum	Detected Maximum
Ruddy Pool	27	23	85.2%	0.3	23
Pool D	17	16	94.1%	0.5	10
Pool C	16	15	93.8%	0.1	7.3
Pool B	15	14	93.3%	0.2	5.3
Pool A	32	25	78.1%	0.2	5.6
Buffalo Creek	30	28	93.3%	0.3	17

Ammonia as Nitrogen (micrograms per liter)

Location	Number of Samples	Number of Detects	Detection Frequency	Detected Minimum	Detected Maximum
Ruddy Pool	24	15	62.5	100	1800
Pool D	15	8	53.3	100	1200
Pool C	14	9	64.3%	100	1200
Pool B	13	2	15.4%	200	500
Pool A	29	14	48.3%	100	600
Buffalo Creek	27	20	74.1%	100	200

Phosphates as Phosphorus (microgram per liter)

Location	Number of Samples	Number of Detects	Detection Frequency	Detected Minimum	Detected Maximum
Ruddy Pool	24	14	58.3%	100	800
Pool D	15	10	66.7%	100	300
Pool C	14	11	78.6%	100	700
Pool B	13	13	100%	100	800

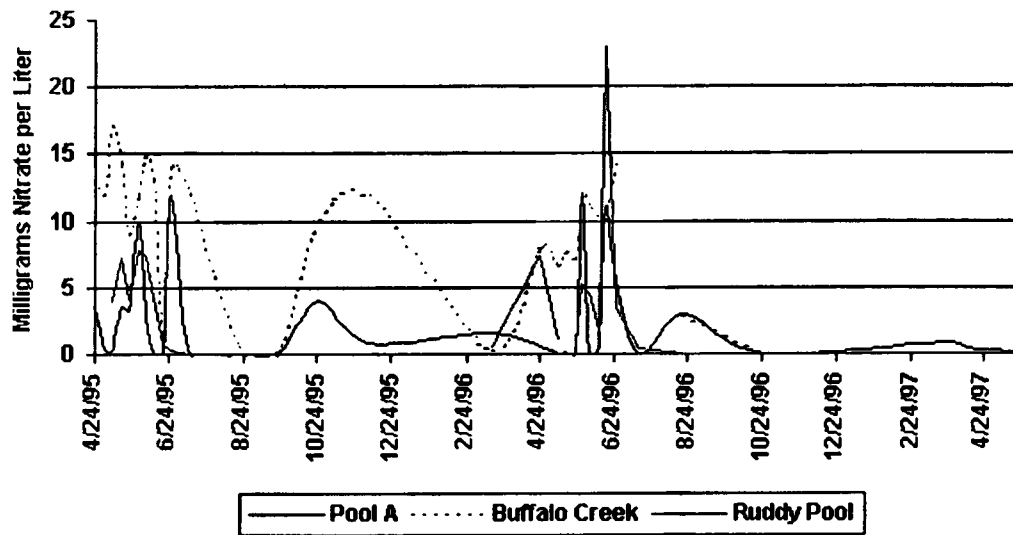
Pool A	29	28	96.5%	100	800
Buffalo Creek	27	25	92.3%	100	400

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Project Chemistry Database File (Microsoft Access)

Seasonal Nitrate Trends



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Tile Drainage Water - Nutrient Data Summary for April 1995 to October 1996

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Nitrate+Nitrite as Nitrogen (milligrams per liter) _____

Location	Number of Samples	Number of Detects	Detection Frequency	Detected Minimum	Detected Maximum
R. Goche's Tile	17	17	100%	3.6	21
Antione's Tile	13	13	100%	22	31
Cushman's Tile	4	4	100%	8.6	17
Stork's Tile	6	6	100%	11	19
Harm's/Gray's Tile	6	6	100%	13	18
County Tile North	4	4	100%	7.2	17
County Tile South	3	3	100%	14	16

Ammonia as Nitrogen (micrograms per liter)

Location	Number of Samples	Number of Detects	Detection Frequency	Detected Minimum	Detected Maximum
R. Goche's Tile	14	2	14.3%	200	200
Antione's Tile	11	1	0.09%	100	100
Cushman's Tile	0				
Stork's Tile	3	0	0.0%		
Harm's/Gray's Tile	1	0	0.0%		
County Tile North	2	1	50%	400	400
County Tile South	1	1	100%	100	100

Phosphates as Phosphorus (micrograms per liter)

Location	Number of Samples	Number of Detects	Detection Frequency	Detected Minimum	Detected Maximum
R. Goche's Tile	14	8	57.1%	100	600
Antione's Tile	11	1	0.09%	100	100

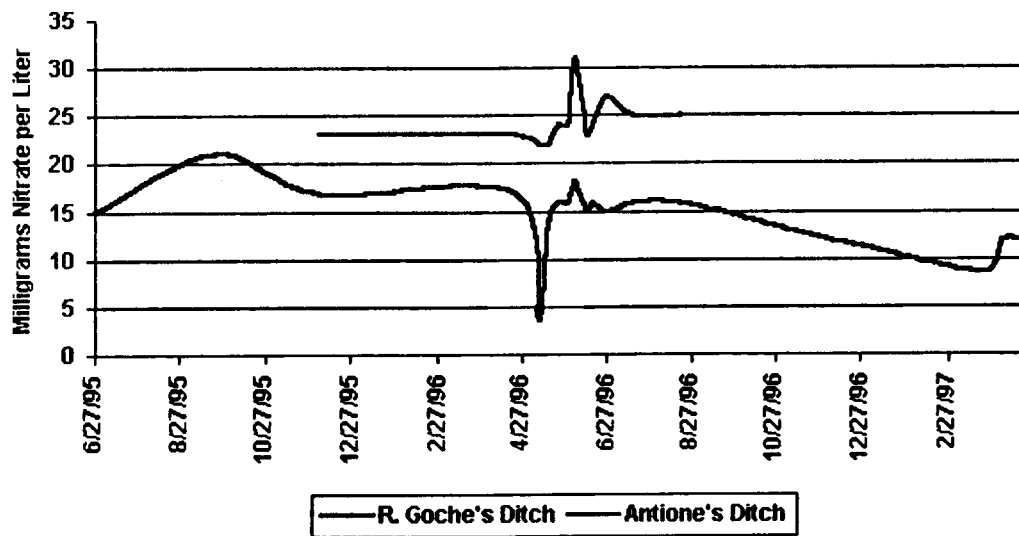
Cushman's Tile	0				
Stork's Tile	3	3	100%	100	300
Harm's/Gray's Tile	1	1	100%	200	200
County Tile North	2	1	50%	300	300
County Tile South	1	1	100%	200	200

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Project Chemistry Database File (Microsoft Access)

Seasonal Nitrate Trends



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Open Water Pools and Rivers - Herbicide Data Summary for April 1995 to October 1996

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Atrazine (micrograms per liter) _____

Location	Number of Samples	Number of Detects	Detection Frequency	Detected Minimum	Detected Maximum
Ruddy Pool	27	9	33.3%	0.1	0.43
Pool D	14	7	50.0%	0.1	1.91
Pool C	14	7	50.0%	0.1	0.45
Pool B	14	5	35.7%	0.1	0.15
Pool A	27	14	51.8%	0.11	5.9
Buffalo Creek	26	17	65.3%	0.12	1.9

Metolachlor (micrograms per liter)

Location	Number of Samples	Number of Detects	Detection Frequency	Detected Minimum	Detected Maximum
Ruddy Pool	27	14	51.8%	0.1	2.7
Pool D	14	11	78.6%	0.22	2.1
Pool C	14	11	78.6%	0.13	1.3
Pool B	14	13	92.8%	0.49	0.84
Pool A	27	19	70.3%	0.1	14
Buffalo Creek	26	20	76.9%	0.13	18

Acetochlor (microgram per liter)

Location	Number of Samples	Number of Detects	Detection Frequency	Detected Minimum	Detected Maximum
Ruddy Pool	27	3	11.1%	0.11	0.33
Pool D	14	0			
Pool C	14	0			
Pool B	14	1	7.1%	0.24	0.24

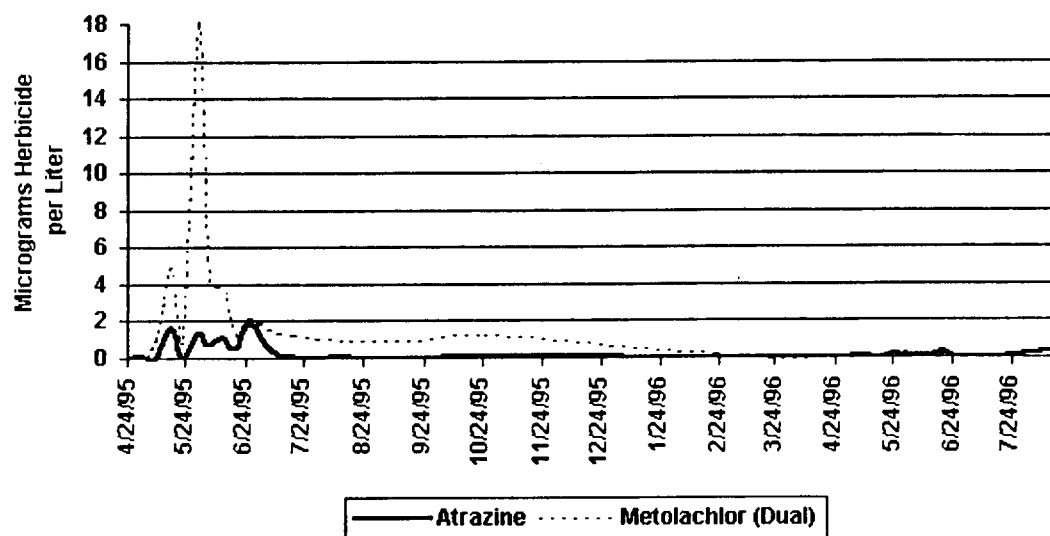
Pool A	27	0			
Buffalo Creek	26	4	15.4%	0.13	1.8

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Project Chemistry Database File (Microsoft Access)

Buffalo Creek Herbicide Chemical Trends



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Open Water Pools Aquatic Sediment Data for July 1995

Chemical values in milligrams per kilogram dry weight, herbicide chemicals not detected.

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Sample Location	% Sand	% Coarse Silt	% Fine Silt	% Clay	% TOC	PO4-P	NH3-N	As	Se	Zn
Pool B North	21.5	24.2	38.5	15.8	16	110	290	4.6	1.6	55
Pool B Center	28	16	43.9	12.1	13	94	290	3.8	1.5	66
Pool B South	76.5	3.2	11.5	8.8	3.4	95	310	4.2	1.5	71
Pool C North	19.2	29.4	34.7	16.7	12	110	340	4.8	2.4	55
Pool C South	20.2	18.1	43.1	18.6	8.5	110	230	4.3	1.8	53
Pool D North	13.3	30.3	40.3	16.1	14	110	250	5.3	3.9	59
Pool D South	20.3	27.9	36.1	15.7	11	96	250	3.2	2.1	55
Ruddy Pool North	13.7	28.7	39.3	18.3	13	100	220	4.5	2.9	56
Mean	24.4	22.2	37.8	15.5	2.3	94.8	248.4	4.04	1.96	55.7
Standard Deviation	20.4	8.7	11.2	3.2	2.4	25.7	82.0	1.06	1.08	11.01
Maximum	76.5	30.3	52.9	18.6	8.5	110	340	5.3	3.9	71

TOC = total organic carbon, PO4 = phosphates, NH3 = ammonia, As = arsenic, Se = selenium, Zn = zinc

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Project Chemistry Database File (Microsoft Access)

Hooded Merganser Egg Data June 1997 (milligrams per kilogram dry weight)

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Location	Reference Number	Development Stage	Percent Moisture	Mercury	Selenium
Buffalo Creek	E-6	3/4	67.6	1.4	ND
Pool A/Buffalo Creek	E-13	Infertile	57.3	0.81	ND
Pool A West	E-5	1/4	67.4	1.8	ND
Pool B East	E-7	Piper	67.3	1.6	ND
Pool B West	E-4	<1/4	65.7	1.5	ND
Pool B West	E-15	Infertile	63.3	1.2	ND
Pool C West	E-3	1/2	66.1	1.8	5.1
Pool C East	E-16	Piper	66.8	2.3	6.1
Pool C East	E-2	Infertile	67.9	1.7	10.2
Pool C East	E-1	<1/4	58.0	3.5	5.2
Pool D West	E-8	1/4	67.0	1.1	9.8
Pool D East	E-17	3/4	58.2	1.8	4.6
Pool D East	E-9	Piper	68.6	2.0	6.3
Ruddy Pool East	E-12	Infertile	67.3	1.3	9.4
Ruddy Pool West	E-11	1/4	62.7	2.6	8.0
Ruddy Pool West	E-18	Infertile	64.8	1.3	9.2

ND = Not Detected; Mercury detection limit = 0.08; Selenium detection limit = 4.0

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The hazard quotient (HQ) procedure was used to predict toxicological risks from direct exposure to contaminants detected in the surface water, aquatic sediments and bird eggs. The HQ is a comparison between the maximum contaminant concentration observed for the study and a toxicity reference value (TRV). Toxicity reference values are available from a variety of government databases and in the scientific literature. The most sensitive test organism species, life stage or type of effect for the TRVs was used to screen for problems. A HQ greater than one indicates that there is the potential to cause harm. A prediction of risk has uncertainties and site specific testing may be needed to confirm adverse effects.

Screening Level Ecological Risk Assessment

Contaminant	Maximum Detected Concentration	Chronic Affect Level	Acute Affect Level	Test Organism and Reference	Hazard Quotient
Water					
Atrazine	5.9 ug/L	1ug/L	19 ug/L	Algae (<i>Selenastrum</i>) (Solomon <i>et al.</i> 1996)	5.9
Atrazine	5.9 ug/L	0.29 ug/L	53 ug/L	Pondweed (<i>Potamogeton</i>) (Solomon <i>et al.</i> 1996, Forney and Davis 1981)	20.3
Metolachlor	18 ug/L	31 ug/L	55 ug/L	Algae (<i>Selenastrum</i>) (Solomon <i>et al.</i> 1996)	0.5
Metolachlor	18 ug/L		70 ug/L	Coontail (<i>Ceratophyllum</i>) (Fairchild <i>et al.</i> 1998)	0.3
Total Ammonia	1800 ug/L	1980 ug/L	10,300 ug/L	Warmwater Fishes (USEPA 1986)	0.9
Total Ammonia	1800 ug/L	4500 ug/L	2460 ug/L	Tadpole (<i>Xenopus</i>) (Schuytema and Nebeker 1999)	0.7
Nitrate	31 mg/L	12.5 mg/L	16.4 mg/L	Tadpole (<i>Rana</i>) (Marco <i>et al.</i> 1999)	2.5
Nitrate	31 mg/L		90 mg/L	Warmwater Fishes (USEPA 1986)	0.3

Sediment					
Ammonia	340 mg/Kg	550 mg/Kg	4800 mg/Kg	Benthic invertebrates (Jaagumagi 1992)	0.6
Arsenic	5.3 mg/Kg	5.9 mg/Kg	17 mg/Kg	Benthic invertebrates (Long and Morgan 1991)	0.9
Selenium	3.9 mg/Kg	2 mg/Kg	4 mg/Kg	Benthic invertebrates (Lemly 1995)	1.9
Zinc	71 mg/Kg	98 mg/Kg	1300 mg/Kg	Benthic invertebrates (Ingersoll <i>et al.</i> 1995)	0.7
Bird Eggs	Dry Weight				
Mercury	3.5 mg/Kg	3 mg/Kg		(Puls 1994 in Custer and Custer 2000)	1.2
Selenium	10.2 mg/Kg	10 mg/Kg		(Puls 1994 in Custer and Custer 2000)	1.02

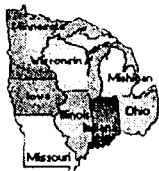
For more information on ecological risk screening and assessment methods see U.S. Environmental Protection Agency guidance documents - <http://www.epa.gov/oerrpage/superfund/programs/risk/tooleco.htm>.

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The concentrations of total phosphate-phosphorus in some of the tile drainage waters that fed into refuge wetlands exceeded on occasion the criteria to control nuisance plant blooms. To prevent the development of biological nuisances, total phosphate-phosphorus should not exceed 50 micrograms per liter (or parts per billion) for any point where it enters a waterbody (USEPA 1986). The maximum concentration of phosphate-phosphorus detected for the study was 600 parts per billion. Phosphates are not typically toxic to aquatic animals (USEPA 1986). Phosphate loading in wetlands can cause blooms of aquatic nuisance plant species and poor water quality conditions (eutrophication) (Wetzel 1983). One pound of phosphorus can equal up to hundreds of pounds of algae in a wetland or lake.

Concentrations of nitrate-nitrogen observed in the open water pools and in the tile drainage waters that discharged in the pools were routinely well above background concentrations. The maximum nitrate-nitrogen concentration detected for the study was 31 milligrams per liter (or parts per million). Nitrate concentrations for tile drainage water from alfalfa, hay and pasture fields range between 0.6 to 5.1 parts per million (van Keuren *et al.* 1979 in van der Valk 1989). There are no restrictive criteria for nitrate-nitrogen to control biological nuisances because it is natural and ubiquitous in the environment (USEPA 1986). Like phosphorus, however, excess nitrate in aquatic systems can cause eutrophication because it is a primary nutrient and fuels plant production.

Nitrate can be toxic to aquatic life. The lethal concentration for sensitive species of tadpoles may be as low as 12.5 parts per million (Marco *et al.* 1999 and Schuytema and Nebeker 1999). The lethal concentrations for fish is 90 parts per million (USEPA 1986). Tile drainage water samples consistently exceeded safe drinking water standards for human health, which is set at 10 parts per million (USEPA 1986). This is a concern if tile drainage water feeds into groundwater aquifers used for drinking water. Refuge wildlife and other mammals that use the refuge are at risk of reduced reproductive potential from drinking nitrate contaminated water.

There appears to be several sources for these two nutrients, phosphate and nitrate. These sources include wetland natural production, surface run-off of fertilizer chemicals and tile drainage water. Natural production includes plant matter recycling in soils and bird feces enrichment in refuge wetlands. Cattail marshes can be naturally rich in nutrients because of high plant productivity and deposition of organic matter followed by the rapid decay during periods of seasonal water level increases (Magee 1993).

Aquatic bird feces may contribute as much as 70 percent of the phosphorus in an aquatic system with low flushing rates (Manny *et al* 1994). High waterfowl use may stimulate the production of algae from the phosphate enrichment of bird feces (Skoruppa and Woodrin 1994). Large flocks of waterfowl and other aquatic bird species use the refuge unit during migration periods and may contribute significantly to the internal phosphate load at the refuge unit during selected and short periods of the year.

Fertilizers that contain anhydrous ammonia and phosphorus were applied annually to the adjacent cropfields. Ammonia products are converted first to nitrite and then to nitrate by bacteria in the soil. Fertilizer chemicals and nitrate may be transported into refuge wetlands by storm water surface run-off from crop fields.

Dissolved nitrate may accumulate in subsurface water below cropfields and contaminate groundwater resources (Stevenson 1982). Cropfield tile drainage water and shallow groundwater were transported into refuge wetlands through the over 65 tile outlet culverts and adjacent permeable soils.

There were periods when nutrient concentrations were low or not detected. This was likely related to two processes. The processes included biological activities and dilution. Nitrate is assimilated by plants and converted to nitrogen by bacterial denitrification in wetland systems (Crumpton *et al.* 1993). Phosphates are used by plants and sorbed to organic matter and sediments (Cooke and Kennedy 1977). Refuge pools were flooded each spring during the study period and un-contaminated rain water may have diluted nutrient concentrations in refuge open water pools. The concentration of nutrients may be diluted if deeper and cleaner groundwater is discharged into refuge open water pools. Deeper groundwater samples collected on five occasions during the study period at a well immediately north of the refuge office adjacent to Pool C and an artesian well on the west side of Pool D did not ever show detectable concentrations of nitrate-nitrogen. A refuge groundwater and surface water mixing model was developed by the U.S. Geological Survey (Figure 6) (USGS 1998). The groundwater and surface water mixing model suggested that groundwater could dilute refuge surface waters under some circumstances related to underlying wetland soil permeability and presence of sand lenses (USGS 1998).

The fate of nitrate was modeled for several areas on the refuge (USGS 1996, USGS 1998 and UIHL 1998). Water discharge rates and nitrate loads for major inputs and outputs around the refuge were estimated using standard procedures. The model predicted water holding times in the open water pools of 2.2 days for high flow conditions and up to 87.2 days for low flow conditions (USGS 1996). The nitrate model illustrated that a larger load of nitrate entered the open water pools than what leaves the refuge through Buffalo Creek and the Blue Earth River. For example, during a moderate to low flow condition (June 1995) about 20,000 gallons of tile drainage water per day were discharged out of both ends of the refuge (USGS 1996). This volume of water carried 650 pounds of nitrate per day (about 119 tons per year) (USGS 1996). There was 461 pounds of nitrate per day (about 84 tons per year) alone discharged into one of the five refuge surface water pools (Pool B) (USGS 1998). We suggest that during low flow conditions and longer water retention time the biological processes decreased the load of nutrients, which resulted in less being transported between pools and out of the refuge. Nitrate

loads along the length of refuge tributary ditches, Buffalo Creek and between the open water pools did not change during high flow conditions (UIHL 1998). A much higher water volume and nitrate load would be transported from the tile drainage systems into Iowa and Minnesota rivers during some high flow conditions.

The nitrate load stored and processed in the open water pools during certain times of the year when the refuge system becomes more like a shallow lake than a flow through river is used to grow lush aquatic plant beds. The nitrate-altered plant communities had poor habitat suitability for many of the migratory bird species that use the refuge during the breeding season or migration periods. The changes to bird habitat suitability included replacement of diverse submergent plant beds by nuisance algae. Beds of stable submergent plants can provide substrate for invertebrate and forage fish production (Miller *et al.* 1989). The edges of submergent plant beds are important because they can have very high invertebrate and forage fish production (Miller *et al.* 1989). Invertebrates and small fishes are food resources for migratory birds that use the refuge during the spring migration and breeding season. Many of the nuisance plant species found at the refuge do not produce seeds or produce seeds that are of limited value as food for migratory birds that use the refuge during the fall migration (INHS 1959).

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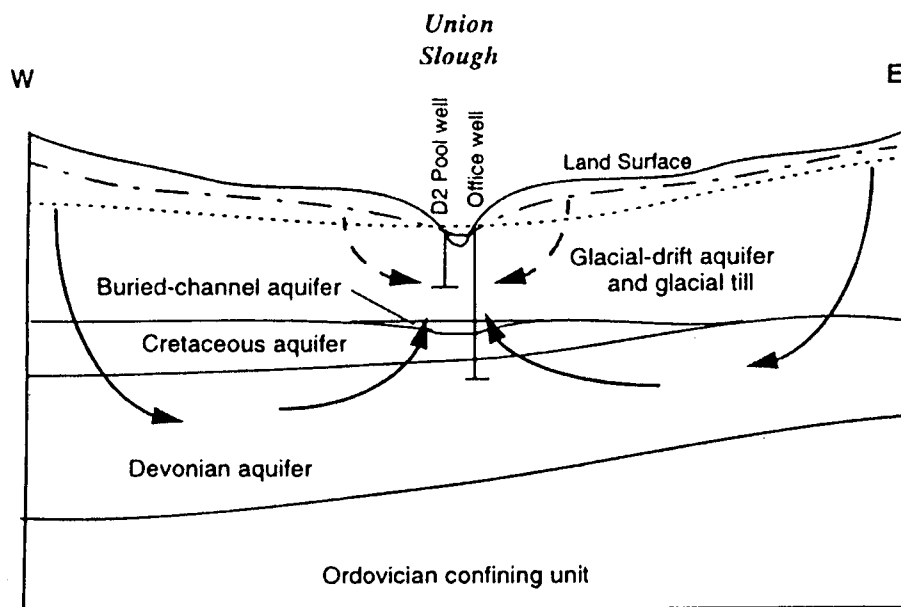
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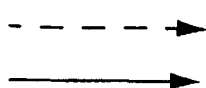


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EXPLANATION

Generalized ground-water flow path



Shallow flow system

Deeper flow system



Hydrogeologic unit contact



Potentiometric surface -- Shows approximate position at which water level in Devonian aquifer would stand in tightly cased wells.



Potentiometric surface -- Shows approximate position of water table in unconsolidated materials (glacial drift/glacial till).



Well indicating total depth

Figure 6. Diagrammatic hydrogeologic cross section along Pool B, Union Slough National Wildlife Refuge, Iowa (from USGS 1998).

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Report Conclusions

Between 1995 and 1997, biologists from the U.S. Fish and Wildlife Service monitored water quality at Union Slough National Wildlife Refuge, Kossuth County, Iowa. The monitoring plan included testing water, sediments and biological specimens for contaminants of concern. Water quality conditions at Union Slough National Wildlife Refuge limited the production of quality food for aquatic birds and maintained less diverse wetlands in an area greater than half of the refuge. Surface water and sediments from some wetlands were contaminated with toxic chemicals (pesticides, ammonia and heavy metals) at concentrations that were below lethal levels but above concentrations that are known to cause adverse effects to aquatic life.

Hazardous heavy metals accumulated in hooded merganser eggs especially at those nests from the northern half versus the southern half of the refuge. Insecticide chemicals were not detected in refuge wetlands. Nonetheless, ecological risk from adjacent insecticide chemical use exists and is unpredictable because an accidental run-off event could occur due to weather or less than perfect application. Wildlife species that use cropfield edges were likely at risk from the ingestion of pesticide contaminated water in puddles, pesticide contaminated forage resources and insecticide granules as grit even if insecticide chemicals did not migrate off of the cropfields. Most refuge wetlands were continually loaded with nutrients from watershed rivers, local upland run-off, groundwater and tile drainage waters in addition to natural marsh nutrient cycling. The cumulative effects from loading nutrients from all these sources seem to be sufficient to cause major changes to the structure and composition of refuge plant communities. The refuge plant communities were dominated by lush growths of nuisance vegetation. These plant communities did not function to provide highly suitable habitats and optimal food resources for migratory birds.

Contaminant Problems

The high nitrate loads from the numerous tile drainage systems fueled blooms of aquatic nuisance plant populations of phytoplankton and other algae in deeper water habitats and maintains monotypic and overly dense native plant populations of coontail or cattail in the shallow water habitats. In some areas the coontail populations were killed out by attached algae growths. The nutrient-altered plant communities cover a large extent of the refuge system. The northeast corner of Pool D provides for an example of a balanced plant community that contains a mixture of submergent plant species such as coontail, pondweeds and Elodea without the blooms of algae compared to Pools C, B and A.

The aquatic plant populations at the refuge today were not apparently affected by early season and low level exposure to the herbicide chemicals. This may be because these plant species that now dominate can quickly recover or recolonize after short-term herbicide exposure periods in high nutrient waters (Lozano and Pratt 1993). However, our concern is that repeated annual herbicide exposure may have the effect of culling sensitive species from plant communities over time and thus reducing refuge biodiversity.

High sediment ammonia concentrations and low dissolved oxygen conditions in the open water pools were symptoms of organic enrichment likely from the over production of plant matter. Bacterial and decomposition processes produce ammonia and sulfide as a by product and consume oxygen from the water. These conditions can become toxic to benthic macroinvertebrate and fish. Fish kills related to dissolved oxygen crashes occurred in August of 1996 and 1997 during the study period.

Insecticide chemicals were not detected in the surface water by the fish biomonitoring plan. This suggests that insecticide chemicals were not transported to refuge wetlands by surface run-off or in the tile drainage water between 1995 and 1997. Nonetheless, wildlife is still at risk of exposure to insecticide chemicals. The risk pathway includes daily migration of wildlife from refuge habitats into the cropfield edges during insecticide application seasons in search of food or grit for their digestive system. Vertebrates are highly sensitive to many insecticide chemicals in use by agriculture. Additional studies are needed to confirm the scale of this problem.

Selenium was detected in the aquatic sediments at concentrations that are reported to be toxic to benthic macroinvertebrates. The results of this study do not allow us to separate out the effects of selenium toxicity, elevated ammonia, low dissolved oxygen and plant community structure on benthic macroinvertebrate diversity. Production of tolerant benthic macroinvertebrate species and other forms of aquatic life (oligochaetes and midge blood worms) do occur in refuge wetlands especially in the mixing zones near outlet structures. It is presumed that selenium bioaccumulates in the tissues of these aquatic organisms and plant parts, these food resources are ingested by fish and wildlife and this is the source pathway for the merganser eggs. Studies show that for ducks to transfer selenium to their eggs selenium must have been part of their diet within two weeks of egg laying and it takes about 10 days of clean diet to level off (Heinz 1993).

The maxim concentration of selenium measured in the merganser eggs was at concentrations that are reported to cause adverse effects in avian species (Ohlendorf *et al.* 1990 and Lemly 1995). The predicted effects include embryo disease, deformities and early mortality. There is no evidence of this problem in mergansers at the refuge based on casual observations (refuge staff personal communication 1999). There is evidence that woodduck (another cavity nesting bird at the refuge) egg hatch success has decreased over the decade, but this is believed to be related to clutch size and nest dumping behavior by young adults (refuge staff personal communication 1999). Additional studies are needed to confirm avian selenium toxicity at Union Slough National Wildlife Refuge.

Contaminant Sources

The primary sources of the pesticide chemicals and nitrate for the refuge were from agricultural practices in an intensively farmed watershed. The primary transportation pathways were surface run-off and tile drainage water. The source and transportation pathways for the selenium is unknown at this time. Additional studies are needed to confirm the selenium sources. Potential sources of selenium in the watershed were from confined animal operation facilities because it is used as a growth stimulate in livestock feed and from seleniferous soils. Selenium toxicity problems in birds are well documented at wildlife refuges in the western United States. The source for the selenium in the west is irrigation drainage water passed through Cretaceous geological era origin seleniferous soils. The modern channel for Union Slough lies in glacial drift and till. The glacial drift and till overly a buried channel and Cretaceous materials. Therefore, potential sources and transportation pathways for selenium were surface run-off of seleniferous soils, leached selenium in groundwater from Cretaceous layers and/or leached selenium in tile drainage water passed through seleniferous soils. Selenium was not detected in 12 surficial soil samples collected on the refuge adjacent to the open water pools, adjoining cropfields and pasturelands within the watershed.

Management Solutions

Water quality in refuge wetlands of course could be improved by targeting the primary water sources. Improved water quality with no toxic chemicals and lower annual nutrient loads may help promote the development of permanent and balanced plant communities throughout all of the open water pools on the refuge. These plant communities could generate high quality seeds and substantial invertebrate biomass on a regular basis to the benefit of waterfowl and migratory bird productivity. Refer to the Recommendations Section of this report for details.

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Cultural eutrophication from nutrient enrichment is the leading problem facing Midwest water resources (ILEPA 1999, USGS 1999, USEPA 1999). Government agencies are considering enforceable water quality standards for nutrients under the Clean Water Act. Refer to Internet URL address "<http://www.epa.gov:80/ostwater/Rules/nutstra3.pdf>" for more information on the proposed national nutrient criteria. The White House has also identified this problem in the Federal Government's Clean Water Action Plan for the Nation. For more information on the Clean Water Action Plan see Internet URL address "<http://www.epa.gov/cleanwater/action/toc.html>".

The water quality at Union Slough Nation Wildlife Refuge may recover or be restored over time by implementing standard lake management strategies to improve current conditions and watershed management strategies to reduce the amount of nutrients from outside sources.

A. Lake Management Strategies

There are two applicable lake management strategies that may be used to guide hypereutrophic shallow water bodies toward desired ecological states (from WIDNR 1995).

1. Drawdowns

Drawdowns help solidify loose sediments which may allow desirable wetland forb communities to develop and utilize excess nutrients in the substrate. A drawdown of surface water will transport dissolved nitrate and herbicide chemicals out of the refuge aquatic system.

2. Water level control

Water level management can be used to match natural fluctuations to stimulate desirable plant communities and restrict the development of undesirable plant communities. Water control may be used to regulate inputs of water from clean sources.

B. Watershed Management Strategies

There are three general watershed management strategies that may be used to control nutrient sources. The three strategies are outlined below and described for consideration in future management plans.

1. Reduce the nutrient source by improving land management practices.
2. Dilute the nutrient source by increasing the flushing rate of the system with clean water.

3. Treat the nutrient polluted water sources before this water enters the system.

Refuge operations specialists have instituted several of these watershed management strategies to date. An artificial chemical treatment wetland was created on private land in 1996 to help reduce nitrogen loads to the refuge. Agricultural producers adjacent to the refuge participated in an U.S. Natural Resources Conservation Service Water Quality Incentive Project in 1996 and 1997. Several parcels of cropland with moderate to high slope that are adjacent to the refuge were purchased in 1996 through 1998 by the U.S. Fish and Wildlife Service for habitat restoration and to benefit water quality. The refuge has in place a Comprehensive Management Plan that includes water quality improvement targets. Kossuth County farmers have received a Land Stewardship Award in 1998 from the Iowa Prairie Pothole Joint Venture for their actions.

Reduce the Source

Nitrate and phosphate loads to the refuge may be decreased by reducing the amount of fertilizer chemicals applied to and transported from the cropfields adjacent to the refuge. This could reduce the amount of nutrient chemicals available to plant resources in refuge surface waters.

There are four approaches to reduce the source of nutrients:

1. Acquiring the lands adjacent to the refuge and restore prior converted habitats.
2. Institute conservation easements for lands adjacent to the refuge and regulate the use of fertilizer chemicals.
3. Stimulate private lands programs. Examples include local environmental quality incentive programs (EQIP) administered by the National Resource Conservation Service (NRCS) and the Watershed Stewardship Incentive program in Iowa. Participants choose enrollment options such as well sampling, conservation tillage, nutrient and pesticide management. For more information on EQIP and other related programs refer to the Internet URL address "<http://www.nrcs.usda.gov/NRCSProg.html>".
4. Develop conservation buffers between refuge wetlands and adjacent cropfields. Buffer strips may be designed to mitigate the transportation of nutrients from cropfields to surface water and groundwater resources. For more information on buffer strips and other related governmental programs refer to the Internet URL address "<http://www.nrcs.usda.gov/NRCSProg.html>".

Internal phosphorus cycling between the water column and sediments may or may not sustain highly productive conditions for some time in the hypereutrophic wetlands. Internal phosphorus loads may be stored in the sediments and rendered unavailable for recycling in mesotrophic waters (McCabe *et al* 1982). After several years of reduced phosphate inputs the system may be guided to a less productive condition.

Dilute the Source

A strategy to dilute nutrient loads in the surface water resources at the refuge is to mix in additional sources of clean water from adjacent rivers or groundwater.

There may not be an accessible source of clean water for the use of increasing flushing rates in the refuge. Shallow groundwater is moderately to highly polluted with nitrate, but deeper groundwater is cleaner for now.

Treat the Source

A strategy to treat nutrient rich water is to route the polluted water through artificial chemical treatment wetlands. Several artificial chemical treatment wetlands placed higher in the watershed and closer to the specific nutrient sources may be more effective than one larger treatment wetland lower in the watershed as is the case for the Union Slough National Wildlife Refuge watersheds at this time (De Laney 1995).

Wetlands can be very efficient in treating (assimilation and conversion) nitrate to less ecologically harmful chemicals such as atmospheric nitrogen gas (Figure 7). The dominant mechanism for nitrate conversion in a wetland is denitrification. Bacterial denitrification accounted for about 80 percent and plant assimilation accounted for about 14 percent of the nitrate removed from a test treatment wetland (Crumptom *et al* 1993).

Chemical treatment wetlands can trap sediments and filter phosphate compounds. Sediment loading may fill an artificial wetland over time and thus require maintenance. An artificial wetland may become saturated with phosphate compounds and the efficiency to filter phosphate may decrease over time.

The function of chemical treatment often reduces the value of an artificial wetland for fish and wildlife habitat, which is a critical trade off. A wetland may respond to nutrient loading by adverse changes in water quality and development of nuisance plants as discussed in this report for the refuge system.

A demonstration artificial chemical treatment wetland was cooperatively built near the refuge by an adjacent landowner (Figure 8). The treatment wetland is one third of an acre and drains about 168 acres. Recent studies now show that a preferred size ratio may be 100 acres of cropfield to one acre of treatment wetland (Crumptom *et al* 1993). The treatment wetland input and output tile drainage waters were monitored for herbicide chemicals and nutrients (Table 6). The demonstration treatment wetland was at times up to 100 percent efficient in changing nitrate to other forms of nitrogen. The treatment parameter that probably most influenced efficiency of this treatment wetland is flushing rate or residence time (volume of drainage water) based on models developed from test plot data for a different study (Crumptom *et al* 1993). Ambient dissolved oxygen conditions can be an important influence on treatment efficiency, anaerobic conditions can increase nitrification rates (Crumptom *et al* 1993). The water quality and dissolved oxygen conditions at the refuge treatment wetland are generally related to type of aquatic plant community, which in turn is related to the management of water column depth.

Creating artificial treatment wetlands along the priority tile drainage outlets for the refuge would significantly reduce the annual load of nitrate to the refuge system. This may take several generations to complete if watershed farmers are interested in participating.

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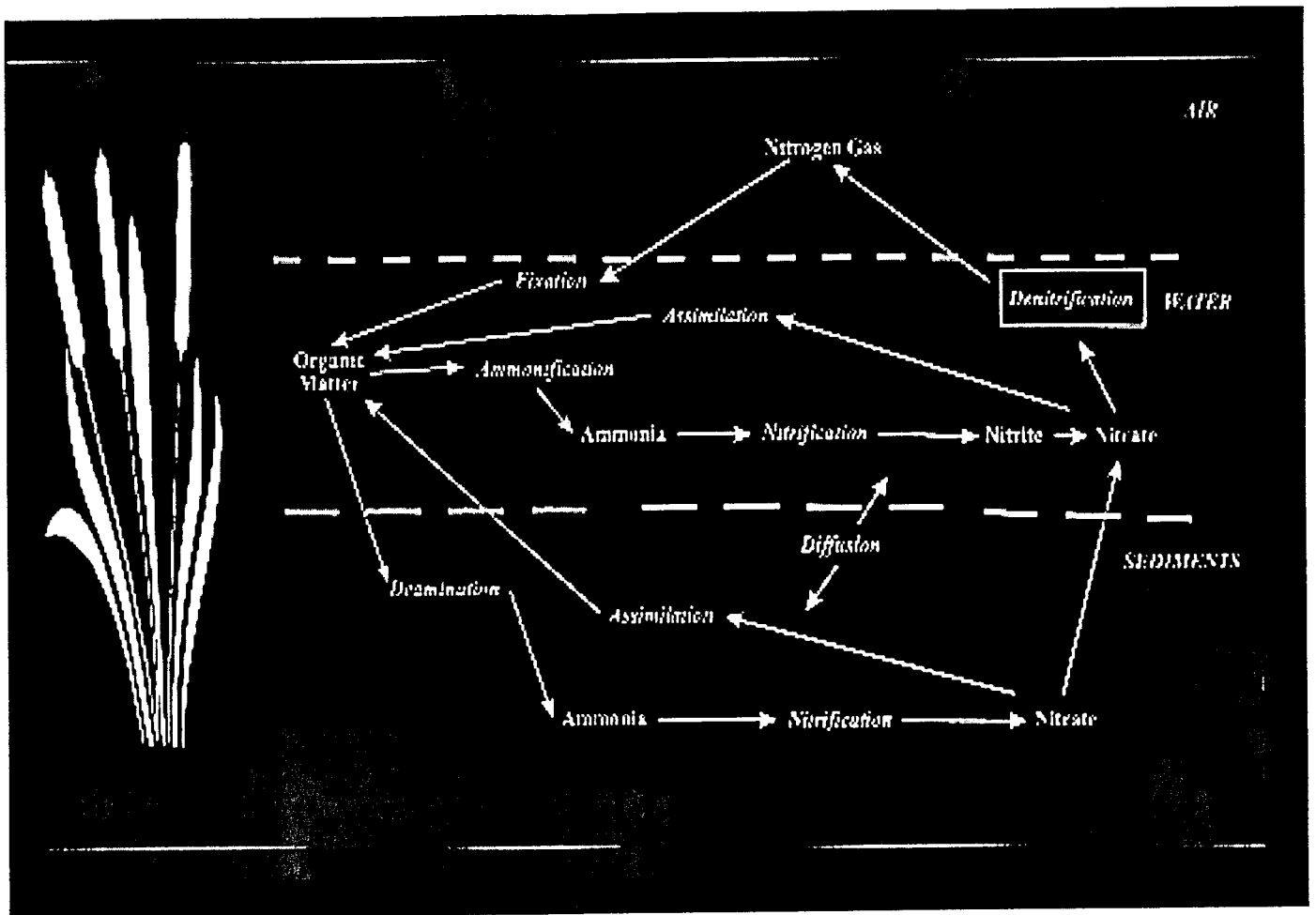


Figure 7. Generalized nitrogen cycle in wetlands.

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Figure 8. Photograph of an artificial nitrate treatment wetland near Union Slough National Wildlife Refuge, Iowa (view to the west). The treatment wetland is located about one mile west of the refuge. It drains 217.6 acres of corn and soybean fields through an 18 inch tile system that enters the treatment wetland at the upper portion of the photograph. The outlet for the treatment wetland is in the lower portion of the photograph. The treatment wetland is 21,000 square feet or one third of an acre in size.

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Treatment Wetland Tile Drainage Water - Nitrate Data Summary 1996 and 1997

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Nitrate+Nitrite as Nitrogen (milligrams per liter) _____

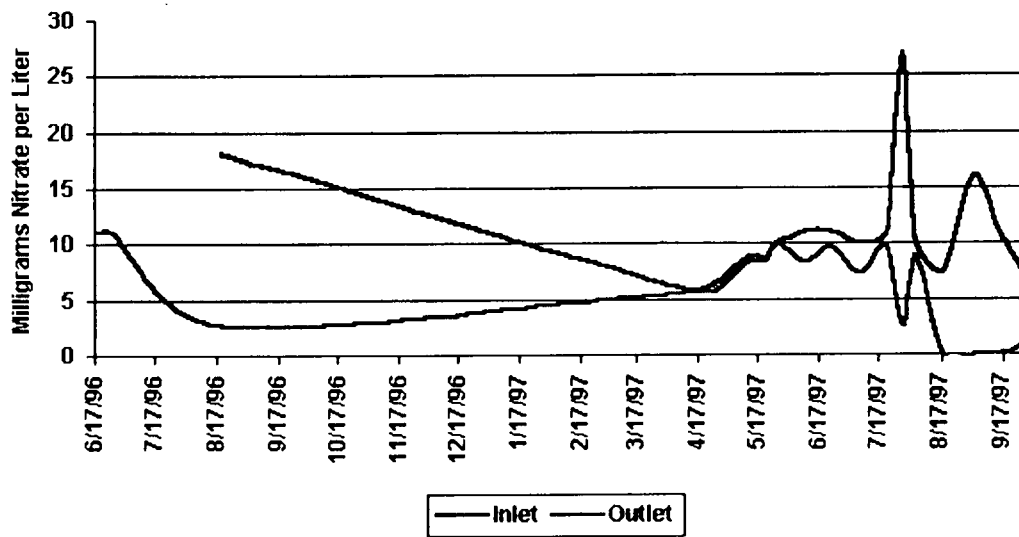
Date	Inlet	Outlet
June 6, 1996		11
June 26, 1996		11
August 19, 1996	18	2.7
April 9, 1997	6	5.6
April 24, 1997	6.3	5.6
May 12, 1997	8.8	8.4
May 20, 1997	8.7	8.4
May 27, 1997	10	10
June 9, 1997	11	8.3
June 23, 1997	11	9.8
July 7, 1997	10	7.4
July 21, 1997	11	9.8
July 29, 1997	27	2.5
August 4, 1997	10	8.8
August 18, 1997	7.5	0
September 2, 1997	16	0
September 15, 1997	11	0
September 29, 1997	7.1	0.9

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Project Chemistry Database File (Microsoft Access)

Seasonal Nitrate Trends



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